Paying for Improved Electricity Services in Developing Countries: Any Role for Previous Mitigation Action?

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State of the Nigerian Energy (Electricity) System

- Population of over 167 million people
- Approximately 7,000 MW of installed capacity, but only average 3,500 MW of available capacity
- Per capita electricity consumption has been less than 150 kWh per annum (World Development Indicators, Little Green Data Book 2011);
- Connected population experiences power problems 60% of the time
Mitigation Action (close substitute)
Some Statistics


- The recent GBI Research’s report: the importation of generator sets in Nigeria is expected to grow to about N151.16 billion ($950.7 million) by the year 2020 from N71.55 billion ($450 million) in 2011 (Nigerian Vanguard, April 5, 2013): http://www.vanguardngr.com/2013/04/generator-sales-in-nigeria-to-hit-n151bn-by-2020/
Key Research Questions:

- *What effect does the previously taken action to mitigate the welfare impacts of power outages have on consumers’ WTP decisions?*

- *What is the relationship between the WTP behaviour of this group of consumers and the cost of mitigation?*
Consumer Behaviour

Rationality vs. Behavioural

- Faiths and beliefs, expectations and context, needs, motives and desires affect people’s behaviour (Bazerman & Moore, 2009; Gilovich et al., 2002; Hastie & Dawes, 2001; Simon, 1955, 1972)

- Consumption behaviour can also be influenced by the method of payment (Hirschman, 1979; Prelec & Simester, 2001); the time between payments and the benefits (Gourville & Soman, 1998); the way payments are ‘framed’ (Gourville, 1998); and the extent to which payments are ‘bundled’ (Chetty et al., 2009; Morwitz et al., 1998)
WTP for Electricity Studies Focus so Far

- Outage duration, outage frequency, income, age, gender, house type, employment status, years of residence in the area, holding of bank account could be significant, family size, billing accuracy, household head’s education, and having more school going children (see Abdullah & Mariel 2010, 2011; Carlsson & Martinsson 2007, Carlsson & Martinsson 2008; Gunatilake, Maddipati, & Patail 2012; and Gunatilake, Patail, & Yang 2012)
But how about the impact(s) of this on WTP?
Own Generation and WTP - A Simple Model

Individuals derive utility from the consumption of two classes of goods: (1) their own stock of electricity \( (E) \) and (2) goods that yield direct satisfaction, but do not affect electricity stock \( (X) \).

\[
U = U(X, E) \tag{1}
\]

The stock of electricity capital is determined by the production function

\[
E = E(G; \pi, \delta) \tag{2}
\]

The leisure time is related to the stock of electricity services as

\[
T_l = L(E)
\]

An individual household maximizes its utility subject to Eq. (2) and the full income budget constraint in Eq. (3):

\[
XP_x + GP_G + WT_L = WT + A \tag{3}
\]

This yields

\[
\frac{\partial A}{\partial \pi} = -\frac{E \pi P_G}{E_G} \tag{4}
\]
Modelling WTP

- Respondents are offered two rounds of questions with the second being contingent upon the response to the first one.

- If the response to the first bid \((B_i)\) is yes (or no), the follow-up question uses a higher \((B_i^h)\) (or lower, \(B_i^l\)) bid value.

- This leads to four different response categories: “yes-yes”, “yes-no”, “no-yes” and “no-no”.
Following Hanemann et al. (1991), the likelihoods of these outcomes are:

\[ \gamma^{yy}, \gamma^{yn}, \gamma^{ny}, \text{ and } \gamma^{nn} \]

The log-likelihood function of the responses is:

\[
\ln L(\theta) = \sum_{i}^{N} \left\{ I_{i}^{yy} \ln \gamma^{yy}(B_{i}; B_{i}^{h}) + I_{i}^{nn} \ln \gamma^{nn}(B_{i}; B_{i}^{l}) + I_{i}^{yn} \ln \gamma^{yn}(B_{i}; B_{i}^{h}) + I_{i}^{ny} \ln \gamma^{ny}(B_{i}; B_{i}^{l}) \right\} \]  

(9)
Survey of households in Nigeria - Lagos and Osun states
On average, over 55% of respondents own a backup generator.

Figure 1: Weekly frequency of outage by LGA
Figure 2: Duration per outage by LGAs

<table>
<thead>
<tr>
<th>Percentage</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>21.2</td>
<td>Up to 1 hour</td>
</tr>
<tr>
<td>12</td>
<td>1-2 hours</td>
</tr>
<tr>
<td>13.4</td>
<td>2-3 hours</td>
</tr>
<tr>
<td>14.7</td>
<td>3-5 hours</td>
</tr>
<tr>
<td>12.7</td>
<td>5-8 hours</td>
</tr>
<tr>
<td>12.3</td>
<td>8-12 hours</td>
</tr>
<tr>
<td>13.5</td>
<td>Over 12 hours</td>
</tr>
</tbody>
</table>

Legend:
- Surulere
- Kosofe
- Ifako-Ijaye
- Ifo Central
- Osogbo
- Iwo
### Estimation Results: Selected Parameters

<table>
<thead>
<tr>
<th>Dependent Variable: WTP</th>
<th>Model 1</th>
<th>Model 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>39.52 (99.02)</td>
<td>40.51 (98.78)</td>
</tr>
<tr>
<td>Generator Ownership</td>
<td>217.09** (106.94)</td>
<td>225.55** (106.59)</td>
</tr>
<tr>
<td>Income</td>
<td>-4.71 (33.45)</td>
<td>0.10 (33.37)</td>
</tr>
<tr>
<td>Freq. of outages</td>
<td>6.26 (5.23)</td>
<td></td>
</tr>
<tr>
<td>Duration</td>
<td>10.20 (17.47)</td>
<td></td>
</tr>
<tr>
<td>Outage time</td>
<td></td>
<td>3.26** (1.27)</td>
</tr>
<tr>
<td>Prepaid customer</td>
<td>420.13** (150.02)</td>
<td>419.84*** (147.63)</td>
</tr>
<tr>
<td>Shared house/single room</td>
<td>-347.12** (130.88)</td>
<td>-321.98** (130.82)</td>
</tr>
</tbody>
</table>
The ownership of a backup generator significantly increases the WTP by N225.55 ($1.45) on top of the monthly bill ($32.45), representing about 2.5% of the current average bill (N5038).

But couldn’t this WTP difference be due to other factors, e.g. differences in the characteristics of the two groups?

Can we evaluate the counter-factual, i.e., what WTP of households with a generator would have been, had they not had a generator?
Matching

- We use Matching Method to overcome the problem (see Dehejia & Wahba, 1999; Heckman et al., 1997)

- Matching eliminates/reduces the bias in evaluating the impact of the generator on WTP when the comparison of WTP is performed using households which are as identical as possible

- Suppose we have data on $T$ backup households and $K$ non-backup households, and a vector $Z$ of variables which help predict whether or not a household has a backup generator

- Rosenbaum & Rubin (1983) has shown that matching can be performed using $p(Z)$ rather than $Z$ - where $p(Z)$ represents the probability of having a backup generator conditional on $Z$, (i.e. the propensity score)
Matching - Results

- Respondents/household heads with a backup are more likely to be males, have higher income, have a home business, younger, have less number of people living together, less likely to live in a shared house, and less likely to live in Osun state.

<table>
<thead>
<tr>
<th></th>
<th>Nearest Neighbour</th>
<th>Kernel Estimator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Treatment Effect</td>
<td>62.86 (141.70)</td>
<td>232.16 (96.01)</td>
</tr>
<tr>
<td>on the Treated</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Average Treatment Effect from Matching Algorithms
Standard errors in brackets

- Households with a backup generator are willing to pay between N62.18 ($0.40) and N232.16 ($1.50) more than comparable non-backup households.
Issues

- The marginal cost (i.e., welfare loss) of power outage should be lower for backup households.

- Consumers don’t always treat previous spending as sunk costs (Genesove & Mayer, 2001; Thaler, 1980).

Both suggest that backup households should be willing to pay less.
Matching - Robustness Checks

- We test for unobserved component effects, e.g. strong preference for uninterrupted supply

- For instance, if the households that have a strong preference for uninterrupted service supply are both more likely to use a generator and are more likely to state a higher WTP amount if they do not have a generator, then matching estimator may find no negative (or even a positive) effect of having a generator on WTP even if it does have a negative effect

- We test how much an unobserved behaviour (e.g., preference for regular energy supply) would have to influence a household’s decision to use a backup generator and the WTP to significantly change the estimation results
Matching - Robustness Checks

- We use the method first suggested by Ichino et al. (2008) using the following steps:
  
  - Make different assumptions to characterize the distribution of the unobserved component (U) in our sample
  
  - We then test under which assumptions of (U), the estimated effect of using a generator on WTP becomes negative

- We find that even if we characterize the distribution of (U) in a way that it has a large effect on the probability that a household uses a backup generator and a large effect on WTP, the estimate of the corresponding effect of using a generator on WTP remains positive

  - It still suggests that backup ownership increases WTP
Possible Explanations

- **Outage time Differential**
  - No statistically significant difference. In fact backup households suffer less outage.

- **Status Quo vs. Preferences for Reliability**

- **Sunk cost Effect - Mitigation Costs**
Possible Explanations

- Sunk cost Effect
  - Household’s problem is to decide and choose optimal backup capacity that minimises the cost of generation capacity and the damage that would result from power interruptions

  - Basically, a household’s cost of generating own electricity is of two components: annual capacity cost of generator, $bG$, and variable cost, $\nu G$

  - The total annual expected cost (in kW) is the sum of the yearly generator and variable cost:

    $$C(G) = bG + \nu G$$
Possible Explanations

- The expected marginal cost of a kWh from own generation is

\[ C'(G)_{kWh} = \frac{b'G}{\pi} + \nu \]

- Result shows that own generation cost is about 49% higher than stated WTP

<table>
<thead>
<tr>
<th>State</th>
<th>(Marginal) variable cost (per kWh)</th>
<th>Unit capital cost (per kWh)</th>
<th>Total (Marginal) cost (per kWh)</th>
<th>Grid price average (per kWh)</th>
<th>Expected avg. WTP Amount per kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lagos</td>
<td>36.24($0.23)</td>
<td>2.22($0.01)</td>
<td>38.46($0.25)</td>
<td>13.28($0.09)</td>
<td>24.55($0.16)</td>
</tr>
<tr>
<td>Osun</td>
<td>29.45($0.19)</td>
<td>1.54($0.009)</td>
<td>30.99($0.20)</td>
<td>12.48($0.08)</td>
<td>23.75($0.15)</td>
</tr>
<tr>
<td>Overall</td>
<td>32.85($0.21)</td>
<td>1.88($0.01)</td>
<td>34.73($0.22)</td>
<td>13.01($0.08)</td>
<td>24.28($0.16)</td>
</tr>
</tbody>
</table>

Table 4: Comparison between the (Marginal) Cost of Own Generation and the Expected WTP Amount
Policy Questions

- Should the government discourage backup generation or encourage it?

- Why not raise quality of electricity supply and then recover through higher charges?

- Should the government (or the regulator) maintain different tariff rates for households with and without backup generators?
Thank You!